INDUSTRIAL HYGIENE SECTION

This Industrial Hygiene Section is published to promote sound thought upon and concerning industrial hygiene. To that end it will contain articles, discussions, news items, reports, digests, and other presentations, together with editorial comments. The editorial policy is to encourage frank discussion. On this basis contributions are invited.

Industrial Medicine

Reg. U S. Pat. Off.

The Editorial Committee will exercise its best judgment in selecting for publication the material which presents most exactly the factors affecting industrial health and developments for control of potentially injurious exposures. The editors may not concur in opinions expressed by the authors but will endeavor to assure authenticity of fact.

The Science, the Law and the Economics of Industrial Health

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The Health of the Worker

—And the Hygiene of the Work Place—

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IN THIS discussion of the past, the present and the future of industrial hygiene, conditions and developments are divided into three periods:

Before the turn of the century,
From that time to date, and
What is to come.

In the past industry did not concern itself very much with injury to the worker. He was expected to accept the hazards of the job. If he got hurt or became ill owing to such hazards, he was not expected to be compensated, since the "assumption of the risk" by the employee was the accepted order of the day and one of the legal defenses in the event of a suit by the injured employee.

Two additional defenses against suits for damages were available where a man was hurt on the job from his own fault or where a careless fellow-worker contributed to his injury. Consequently management took little thought in the past toward prevention of accidental injuries or to control of industrial health hazards.

Beginning of Present Constructive Attitude

THE start of the present constructive attitude toward conservation of the life and limb of the worker dates from early in the century when the first compensation laws were enacted. Management began to think of prevention when it found that injuries resulting from accidents and from health hazards were involving considerable losses to industry.

At that time it was largely a surgical and not a medical problem, but gradually the attitude of industry has changed as it has more completely appreciated that the health of the man who went into the job was as important, and even more so, than the treatment of the man who was hurt. Shortly before I became associated with the International Harvester Company, and even before the compensation acts went into effect, we saw the unfortunate string of circumstances resulting when a man became sick was actively considered, and it was felt that provision should be made that he be insured

Subject matter of an Address presented at a meeting of the Chicago Section, AMERICAN INDUSTRIAL HYGIENE ASSOCIATION, October 8, 1941.

when illness caused him to be unable to work. So in 1908-1909, to meet this need, the Mutual Benefit Association was organized.

As benefits were paid under this plan it was found that many men were given jobs for which they were not physically fit and on becoming ill caused the benefit association to incur losses in excess of what was originally anticipated. The desire arose to learn whether a man was physically able to be a good member of the benefit association, and physical examinations were made of all prospective members. Then in 1912-1913 it was only a short jump to universal physical examinations for all applicants for employment. This was put into effect and has continued to this day.

Assumption of the Risk in Occupational Diseases

THE old doctrine of "assumption of risk" was also accepted in connection with the occupational disease hazards. At a plant on the south side of Chicago some large natural sandstone wheels were being used for grinding. These weighed some six or seven tons each. Being interested in the possibilities of effects of inhalation of sandstone dust, a visit was paid to this plant and an old-time foreman of the hard-boiled type was encountered. The foreman admitted that sometimes a worker claimed that he had some congestion on his chest after working at these grinding wheels for a number of years, but belittled the possibility of any actual lung injury arising from the plant operations. The foreman did admit that when such complaints were received from the workers it was considered about time to give the man his paycheck and let him out.

That was in 1913. On further investigation at this plant it was found that these workers began to die after they had been in the employment for five years, and only rarely did such a man remain in service at this operation longer than 10 years. Even then "grinders rot" was being noted in the English medical journals concerning grinding operations in the Sheffield cutlery works. The concept then held of the condition was that more and more dust got into the lungs until they became increasingly filled up with a cement-like mass.

It was 1924 by the time we first heard the word "silicosis." Then little attention was being paid to the health of the worker or to the physical conditions under which he worked.

When the word "housekeeping" was first mentioned to the superintendents of plants in those days, the impatient reply would be that "this plant was built to make things. If you are too clean and pay too much attention to cleaning up all the time you just don't get any work done." But today we give a prize for the best housekeeping. Now good housekeeping is the accepted practice, not only from an accident prevention point of view but also from the point of view of production, employment relations, occupational disease control—in fact from every point of view of proper industrial management.

In the early days some of the plant executives were feeling their way along in this matter of industrial health, but most of them had the attitude that was so often expressed by the mild but firm reprimand: "Remember we are in business to manufacture articles to sell, not to engage in a lot of monkey business."

In those first years, in connection with our general interest in tuberculosis, we noted that many men were obviously extremely undernourished, and that many such men would work long hours of overtime. From early in the morning, with brief periods for lunch and supper, they would come back to work until nine or ten o'clock at night. On examination these men were shown to have nothing organically wrong with them but were just plain tired out. On urging these men to take vacations, they replied that they simply couldn't lose their wages even though their foreman would permit them to leave the job for a week or so.

It seemed imperative that some of these undernourished and hard working men have a vacation with pay if they were to continue to be productive very much longer. After much insistence, and in spite of much apprehension over establishing a dangerous precedent, authorization was obtained to send one man who had been working at the plant for 28 years morning, noon and night on a two-week's vacation with pay. This man was called into the medical department office and told that he was going to have a two-weeks vacation. He replied that he just couldn't afford it, and then the news was broken that this vacation would be with pay. Instead of receiving this news with joy, the man broke down and wept, stating that this was a subterfuge, that the company was going to fire him. After much argument he finally accepted the assurances that his job would be open to him when he came back, but even then he returned to the plant every two days throughout the two weeks to make sure that his job was still there!

The plan of providing vacations with pay for these undernourished groups worked well for a while, but it was merely the start of the vacation with pay idea for all wage earners at the International Harvester Plant —a measure which has the complete support of the management as a desirable employment provision.

Industrial surgery work used to be a very slam bang emergency type. Before the compensation acts became effective, most plants had one of the workers designated as a first-aid man. This man would consider himself adept at such delicate tasks as removing particles from eyes. One favorite method was that of licking it out with his tongue! But with the entrance of compensation this haphazard first-aid treatment tended to change. Compensation provided the necessary pressure to bring about proper surgical services.

The present rule for surgical care for those injured on the job is "*Whatever* is necessary, promptly and efficiently rendered, and as long as necessary." In the International Harvester Company, if an injured worker requires a private room and three nurses to live up to this precept he gets such facilities.

Physical Examinations

WHEN pre-employment physical examinations were first inaugurated, many a girl or young man was turned down for minor reasons. In those days 5 to 10% of the applicants were rejected on the basis of their medical examination. In one Chicago industry such rejections were as high as 33% of all applicants. Today we make physical examinations for placement and if there are more than 1½% rejections, we think there is something the matter with the examiner.

Even though physical defects appear to be severe, we have learned the value of the rule "Don't reject too many workers even where there is physical disability." Just because a skilled tool man has one bad eye, this is not grounds for rejection. The only reason for rejection is whether his physical infirmity would cause him to be a hazard to himself or to other employees on a given job.

In order to keep a check on the health condition of our workers we give every one of them a physical examination every three years. All men who are in charge of other workers are examined every year, as are those who are exposed to a potential health hazard

in connection with their work. Where there is exposure to an actual known hazard then the examination is made every six months. Special consideration is given to the group of men who have some physical disablement whom we designate as "B" men. These are examined every six months or in accordance with the needs of their particular handicap.

Along with physical examinations of the workers, various provisions for avoiding illness began to develop. The examining physician began to tie up certain types of illnesses with plant conditions. The first of these was the plant water supply. Where city water was found to be expensive, wells were often drilled and often these wells did not produce potable water. At one plant the first well struck oil; the second, coal; and never was proper drinking water obtained. At a plant in a small town in Ohio, seepage from a city sewer system found its way to the plant artesian well. In the effort of the owner to avoid payment for city water, he lost his plant in meeting the compensation payments for typhoid fever cases. Today it is accepted practice to provide city water for industrial drinking purposes.

Forty years ago the tuberculosis rate in Chicago industries was as great as for the city—200 to 250 per 100,000.

Today in the Chicago plants of the International Harvester Company, the tuberculosis rate among the employees is down to a quarter of that for the community even though the rate for the community has itself been cut to a quarter of its previous level.

Other contagious diseases such as small-pox took their toll. Among the colored men, the religious leader usually organized the gang and was the head of it. It happened in one case that "the reverend" became sick and had to stay home. Nearly every colored man in the gang visited him the next day and soon practically the entire number of them were laid up in bed with small-pox!

Up to a few years ago heat prostration claimed its victims. Not a summer went by without a number of deaths. Right here in Chicago there would be three or four such fatal cases every summer. At the present time this situation has been so rectified that in the last four years there hasn't been a single heat prostration death.

Our whole organization has instructions that a man with heat prostration must never be left alone and even though his temperature may be at 108 or 109° F, by getting the patient to a hospital under continual observation and treatment, he can be saved.

Chest X-Ray Examination

ONE of the developments during the past few years has been the increased use of chest x-rays. These x-rays bring out conditions in the lungs of the man which even the experienced doctor cannot pick out on clinical examination. Some 30,000 chest plates of apparently healthy persons, both applicants for jobs and men on the payroll, have now been taken and not only have tuberculosis cases been picked up but also other conditions such as enlarged hearts and aneurisms which would on ordinary physical examination be missed.

Physical Equipment

TREMENDOUS strides have been made in the improvement of physical equipment so that better working environment can be provided for the worker. Good light, uncontaminated air, pure water, proper temperature conditions are today the accepted standards. Even though good working conditions are the usual thing, it was surprising the other day to step into a foundry within 150 miles of Chicago that was actually air-conditioned.

As an indication of the effect of environment on the difficult problem of the common cold, the incidence of this disease among our office workers when working under crowded conditions in a building which depended upon the opening and closing of windows for its ventilation was even more than that among our factory workers. On moving to a modern building provided with air conditioning and where adequate room did not necessitate the crowded conditions, the incidence of the common cold among office workers dropped to less than half of that among workers in the shops.

Just how much of this improvement is attributable to the air conditioning and how much is due to lack of overcrowding can hardly be determined, but the effect of the improvement in working conditions among this group is certainly striking.

The Future

WE ARE too prone to think of industry as a development of the big plant only. We tend to forget that a large percentage of workers are engaged in small plants. The question comes up "Why should we be interested in the small plant and its workers if we are connected with a big industry?"

A characteristic of labor is that it does not stay put in one place and, because labor tends to shift, the man connected with the big industry must also include an interest in medical service in all industry. In the past most of the industrial doctor's service was in surgery; in the future most of it will be in medicine.

There is a big field which needs to be filled in industrial medicine instruction. More of the industrial angles should be included in medical education. The industrial doctor should know what an industrial hazard looks like so that he will recognize it if it is present in the plant under his supervision.

The military tank is a timely example of the occupational disease hazard in every step of production. Starting with the mining of the iron ore where the miner may be exposed to a silicosis hazard; continuing to the railroad transporting the iron ore where the laying of ties may involve a skin condition from contact with impregnating chemicals; during the actual fabrication of the tank; and even where it rolls off the production line and under its own power produces the hazard of carbon monoxide poisoning from its exhaust pipe—every one of these steps involves a potential occupational disease hazard, except possibly the gold that goes into its cost and I'm not so sure but what there is some occupational disease there!

Much progress continues to be made both in safety and in occupational disease control. The man is now safer at work than he is on the street. But as soon as the slump comes after the present peak of production, a great many of the present workers will not have jobs. After being severed from the payroll many a worker will say that he is sick and that he will collect some compensation. And believe me, he will! So, both for the future and the present, we must today make every provision to see to it that the health of the worker is properly maintained and that proper provision is made for hygiene in the plant.

[NOTE: DR. BRITTON'S retirement from his 30 years as Supervisor of Medical Service for International Harvester was announced shortly after the date of the foregoing presentation (INDUSTRIAL MEDICINE, November, 1941, pp. 478-480). On November 1, he was succeeded by DR. WILL F. LYON, long Chief Surgeon for the company.]

Aerosol Sterilization of Air-Borne Bacteria

A. E. WILLIAMSON *and* H. B. GOTAAS

AIR, as a vehicle for the transmission of bacterial infection, has been studied since the initial experiments of Pasteur. Lister, in 1868, introduced carbolic acid into the operating theatre to disinfect the air.

Following the discovery that micro-organisms were causative agents of many diseases, it was observed that infection could be transmitted by food, drink, and numerous other means and, in 1898, Flugge[1] reported that droplets of mouth spray settled a very short distance from their source. The concept of air-borne infection was practically abandoned.

The early work of Wells[2, 3] on droplet nuclei and his later work on air bacteriology have created renewed interest in air disinfection.

Trillat,[4] in 1938, reported concerning the sterilization of air by atomizing germicidal mists or aerosols. The aerosol consists of small droplets or mist particles about 1-2 microns in diameter of a germicidal solution. The basis for the germicidal action of the droplets in air is considered to be that each small droplet contains the same concentration of effective germicide as the parent solution which is atomized and will destroy a bacterium when it comes in contact with it in the air. Hence a very small quantity of germicidal agent may be dispersed as a fine mist throughout an enclosed space and cause disinfection. Trillat[4] suggests that the efficacy of these minute traces of germicide in air is due to the fact that the bacteria are in a very vulnerable condition when suspended in the air. Their vulnerable condition in air is partially indicated by the fact that their disappearance rate in air is very high.

Pulvertaft and associates[4] and Twort and associates[5] have studied in detail the effectiveness and action of several different aerosols and have found resorcinol and hexa-resorcinol to be the most effective. Masterman[7] reported that hypochlorous acid gas from spraying hypochlorite solutions into air was effective in very low concentrations as a germicide for air-borne bacteria. There appears to be considerable difference in opinion between Masterman and the Twort group as to how hypochlorites act as an air germicide.

This investigation of the effectiveness of different aerosols makes use of a somewhat different method of approach in that the rate of natural disappearance of the bacteria from the air was determined in the same experiment in which the effectiveness of the bactericidal aerosol was investigated.

Natural Disappearance of Bacteria in Air

THE natural disappearance or survival rate of bacteria in air which is an adverse environment for them not only is important in studying the effectiveness of bactericidal agents but also fundamental to the satisfactory use of total number of organisms present as an index of ventilation, as suggested by Wells[8] and in the use of an index organism such as the alpha-hemolytic streptococci as measures of aerial contamination. The occurrence of alpha-hemolytic streptococci in the air of schools, theatres, subways, and parks was investigated by Buchbinder, Solowey, and Solotorovsky.[9]

Survival rates of bacteria in mediums other than air have been studied from time to time and it has been noted that the survival or die-away tends to follow a mathematical law. Ikeda[10] noted that the logarithm of the number of surviving organisms plotted against elapsed time closely approximated a straight line. This is the law of unimolecular reaction or compound decrease. Chick,[11] from studies on rates of die-away of bacteria exposed to disinfecting solutions, Winslow and Falk,[12] attempting to correlate the time survival rate, and Phelps,[13] all concluded that rate of die-away of bacteria, whether under the influence of heat, cold, chemical disinfection or other adverse conditions approximately follows the mathematical relationship of unimolecular reaction which may be expressed as follows:

$$\log N_t = \log N_o - Kt$$

where N_t = number of bacteria surviving at any time, t
N_o = number of bacteria present at zero time
K = slope of the curve and the rate of disappearance or survival.

The results of this investigation follow this relationship very well and the data have been analyzed around the value of K, the survival rate.

In order to select an index organism which was satisfactory for use in the aerosol investigation and to have information on its disappearance from air under natural conditions, that is, in the absence of aerosol, the disappearance rates of five organisms, namely, *Serratia marcescens, Escherichia coli, Staphylococcus aureus, Staphylococcus albus,* and *Streptococcus salivarius* were studied.

Generally speaking, the different experiments were carried on under precisely the same procedure. Forty-four cubic centimeters of a suspension of a 24-hour culture of bacteria in distilled water were atomized into a room having a volume of 2,200 cubic feet in which two electric fans always located in the same place kept the air in motion throughout the duration of the experiment. The room was cleaned and ventilated before each experiment. Spraying was done at about 9 feet from the floor and it was demonstrated by the Tyndall cone effect that the atomized droplets were not falling to the floor. An interval of two minutes elapsed between the completion of spraying the bacteria and the beginning of bacterial sampling.

Samples were taken with two series of exposed petri dish plates, having 10 minutes exposure and either a Well's centrifuge,[14] a funnel impinger as described by Hollaender and Dallavalle[15] or an impinger which was a modification of the type of Hollaender and Dallavalle arranged to provide better distribution of the colonies on the petri plate.

Samples of air of 5 or 10 cubic feet volume—depending on the bacterial concentration—were taken with the centrifuge, and impingers, at a rate of one cubic foot per minute. *Serratia marcescens* was grown on nutrient starch agar; *Escherichia coli* on nutrient lactose agar; *Staphylococcus albus* and *Staphylococcus aureus* on plain nutrient agar; and *Streptococcus salivarius* on nutrient blood agar.

It was not convenient to control the temperature or humidity of the room, hence the conditions are similar to what would be expected in an ordinary room.

RESULTS AND DISCUSSION: Fig. 1 shows the observations of natural disappearance and the line of best fit computed by least squares for a typical disappearance experiment for each of the five organisms. The ordinate scale representing the number of organisms surviving at the time of sampling as a percent of the number present at the start is logarithmic and the

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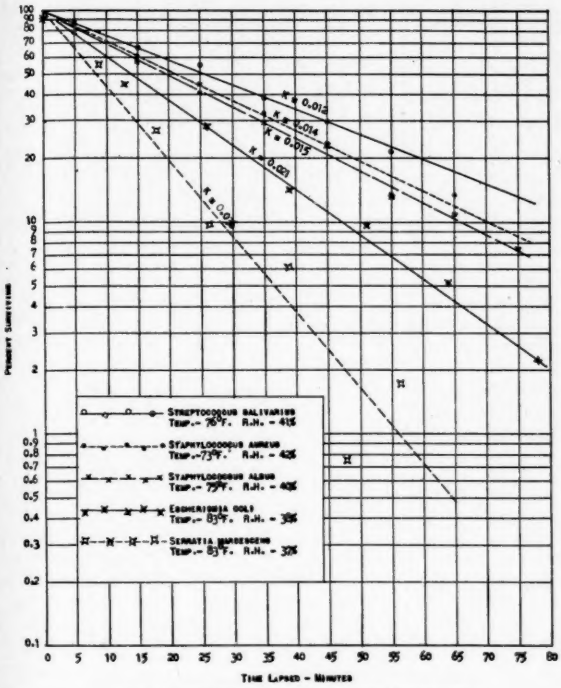

FIG. 1 - TYPICAL NATURAL DISAPPEARANCE CURVES FOR BACTERIA IN AIR

abscissa representing time is arithmetic. Hence the unimolecular equation for disappearance plots as a straight line. It may be seen that the experimental points follow the line of best fit reasonably well. This has been checked by computing the co-efficient of correlation for some of the curves in the various experiments.

TABLE I.
RELATION OF RELATIVE HUMIDITY AND TEMPERATURE TO DISAPPEARANCE OF BACTERIA

Organism	Rate of Disappearance K	Relative Humidity %	Temperature ° F.	Sampling Device
Staphylococcus albus	0.015	40	75	Exposed plates
	0.017	52	78	M. impinger
	0.018	52	78	Funnel impinger
	0.022	60	79	Exposed plates
Staphylococcus aureus	0.0107	32	76	Exposed plates
	0.012	37	74	Exposed plates
	0.013	37	74	Exposed plates
	0.013	37	82	Exposed plates
	0.014	42	73	M. impinger
	0.014	42	73	Exposed plates
	0.015	37	82	Exposed plates
	0.018	62	81	Funnel impinger
	0.019	62	81	Exposed plates
	0.019	74	78	Funnel impinger
	0.019	66	84½	Exposed plates
	0.020	66	84½	Funnel impinger
	0.021	62	81	Centrifuge
Escherichia coli	0.019	30	81	Funnel impinger
	0.021	38	83	Exposed plates
	0.033	48	76	Exposed plates
	0.034	48	76	Centrifuge
	0.038	48	76	Funnel impinger
Streptococcus salivarius	0.012	41	76	Funnel impinger
	0.013	41	76	Exposed plates
	0.014	52	78	Funnel impinger
	0.015	52	78	Exposed plates

Table I shows the rate of disappearance arranged in ascending order for each of the different organisms at different temperatures and relative humidities. The influence of temperature on the disappearance rate, K, for the narrow range of temperatures used does not appear to be significant. However, although there are insufficient observations to permit an extended statistical analysis of the quantitative relationship of disappearance to relative humidity, the results do clearly show that the rate of disappearance increases as the relative humidity increases. Some inconsistencies are observed in the *Staphylococcus aureus* data. For example the K of 0.015 with a relative humidity of 37% is larger than the K with a relative humidity of 42%. This may be due to the effect of slight sampling errors since K represents the slope of the line of best fit to the observed points.

The rate of disappearance, K, for *Staphylococcus albus* is increased 47% from 0.015 when the relative humidity was 40% and the temperature 75° F. to 0.022 when the relative humidity was 60% and the temperature 79° F. Ninety-nine per cent of the bacteria would disappear in 133 minutes at a relative humidity of 40% while only 91 minutes would be required for 99% disappearance at a relative humidity of 60%. The rate of disappearance, K, for *Staphylococcus aureus* in the relative humidity range between 37% and 62% increased slightly over 50% which is about the same as for *Staphylococcus albus*. In the relative humidity range between 41% and 52% the rate of disappearance of *Streptococcus salivarius* increased about 14% which is a proportionately smaller increase than that of the *Staphylococci*.

The rate of disappearance of *Escherichia coli* increased from 0.019 to about 0.034 with a change in the relative humidity of only 18% (30% to 48%) and from 0.021 to 0.034 when the relative humidity increased only 10% (38% to 48%).

Wells,[16] in studying bacterial contamination of air in textile mills, found that the rate of disappearance, K, of *B. coli* increased with an increase in the relative humidity. Wells[1] also states that increasing the relative humidity from 45% to 90% more than doubled the disappearance of *B. coli*. His results show the disappearance rate, K, for *B. coli* as 0.0196 when the average relative humidity was 34.75%. This compares closely with the values 0.019 and 0.021 for relative humidities of 50% and 38% respectively.

No explanation has been offered as to the reason for the increased disappearance with increased relative humidity and for the present one can only speculate concerning the reason. It is well known that coagulation of protein is increased in certain bactericidal reactions, when water is present. Paul, Birstein, and Reuss[17] concluded that in drying *staphylococci* on garnets, death was due to the germicidal action of oxygen. Humidity probably affects the settling characteristics of the bacterial cells and the tendency for them to adhere to surfaces with which they come in contact. In these studies sedimentation was minimized by keeping the air in motion with fans, however, five and one-half hours after atomizing the bacteria into the room, swabs taken from the floor and walls and smeared onto petri dish plates showed that the index organism could be recovered. The air samples had ceased to show more than one or two and usually there were no index organisms in 10 cubic feet of air. Increased relative humidity may cause the bacterial cells to tend to clump while in the air, thus one clump growing as a colony when sampled might contain several cells which earlier were individual cells or more than one clump. Wells and Fair[18] have shown that increased relative humidity increases the vulnerability of organisms to ultra-violet sterilization.

Comparison of the disappearance rates obtained by different sampling devices at the same time (shown by the same relative humidity and temperature in

Table I) indicates that the disappearance rate does not vary appreciably with the method of sampling. However, simultaneous test experiments with the centrifuge, funnel impinger, and modified impinger, showed that the centrifuge, although erratic, usually recovered the largest number of bacteria, followed by the funnel impinger, then the modified impinger.

Table II shows the disappearance rates for the five organisms studied at an approximately constant relative humidity. These different organisms show considerable variation in their resistance to drying and to the adverse environment of the air. *Serratia marcescens* (*B. prodigiosus*) and *Escherichia coli* which are more distantly removed from their natural habitat exhibit higher disappearance rates than *Staphylococcus albus*, *Staphylococcus aureus* and *Streptococcus salivarius* which are more frequently found in contaminated air.

TABLE II.
DISAPPEARANCE RATES OF VARIOUS ORGANISMS AT APPROXIMATELY CONSTANT RELATIVE HUMIDITY

Organism	K	Relative Humidity
Serratia marcescens.....	.036 - .043	37
Escherichia coli ..,.....	0.019 .0196 (Wells)	.021 30 - 34.75 - 38
Staphylococcus albus	.015	40
Staphylococcus aureus ...	.013 - .015	37
Streptococcus salivarius ..	.012 - .013	41

In accordance with the values of K in Table II the time for 99% disappearance of the bacteria is as follows:

Serratia marcescens .....0.036 - 56 minutes
Escherichia coli .....0.021 - 95 minutes
Staphylococcus albus .....0.015 -133 minutes
Staphylococcus aureus .....0.013 -154 minutes
Streptococcus salivarius .....0.0125-160 minutes

Serratia marcescens and *Escherichia coli* seem to be the classic organisms used in air contamination studies because of their ease of cultivation and identification, however, due to their high disappearance rates they do not serve as well as index organisms when disappearance rates must be considered in control tests for air disinfection. This difference in viability in air is no doubt due to several different factors, one of which may be that the *Staphylococci* and *Streptococci* usually occur in clumps or chains, while *Serratia marcescens* and *Escherichia coli* usually are single cells. Some of the cells of each clump or chain may have been destroyed before sampling, but in sampling the clump or chain would produce only a single colony whether there were several or only one cell in it. It was difficult to obtain consistent sampling results using *Serratia marcescens*. *Staphylococcus albus*, *Staphylococcus aureus*, and *Streptococcus salivarius* show approximately the same disappearance rate, however, *Staphylococcus aureus* has advantages as an index organism for air disinfection studies in that it is easier to identify than *Staphylococcus albus* and easier to identify and cultivate than *Streptococcus salivarius*.

Aerosol Sterilization

SINCE the natural disappearance of bacteria in air closely follows the logarithmic pattern with respect to time, and since sterilization is accelerated die-away, the effectiveness of an aerosol bactericide should be indicated by the increase in the rate of disappearance after the aerosol bactericide has been atomized into the air as compared with the natural rate of disappearance in the absence of the aerosol bactericide.

With the above criterion as a basis of effectiveness, different aerosols were studied by atomizing them into the room air using two different procedures similar to that of the disappearance rate studies. (1) The aerosol bactericide was first atomized into the room air, the fans being in operation, and then the suspension of bacteria was sprayed. Sampling was started two minutes after the completion of spraying bacteria and continued through the period of the experiment. The rate of disappearance under this condition was compared with the rate of disappearance at approximately the same relative humidity as determined in the previous studies. (2) The bacterial suspension was sprayed into the room in exactly the same manner as followed in the natural disappearance studies. Sampling of the air was begun two minutes after the completion of spraying the bacteria and continued throughout the period of the experiment. At least three samples, usually extending over a period of 30 minutes, were taken to determine the rate of natural disappearance. After these samples had been taken, the aerosol was atomized into the air and sampling continued. The observations which were made at regular intervals following the atomizing of the aerosol indicate the efficacy of the aerosol. When these observations fit the extension of the line of natural disappearance (the first three observations) or when one line fits all observations, the rate of disappearance of the bacteria from the air has not been affected by the aerosol. When the slope of the line through the observations made after addition of the aerosol is steeper than that of the natural disappearance, the aerosol has increased the rate of disappearance of the bacteria from the air; that is, has exerted bactericidal action.

Staphylococcus aureus was used as the index organism in the aerosol studies.

The solutions of different aerosols were atomized into the air with a DeVilbiss No. 15 atomizer operated by compressed air. The orifice of the atomizer was altered to make it deliver fine droplets.

RESULTS AND DISCUSSION: Figs. 2 to 7 show some more or less typical results of experiments with different aerosols. The mist concentration stated on all the figures is the ratio of the volume of aerosol atomized to the volume of air into which it was atomized.

Fig. 2 shows a disappearance curve when a 70% solution of ethyl alcohol was atomized into the air for 14 minutes starting 30 minutes after the bacteria had been sprayed. The first three bacterial counts represent the natural disappearance. If the alcohol solution had been effective as an aerosol bactericide, there should have been a break in slope between the lines of best fit to the observations. That is, the disappear-

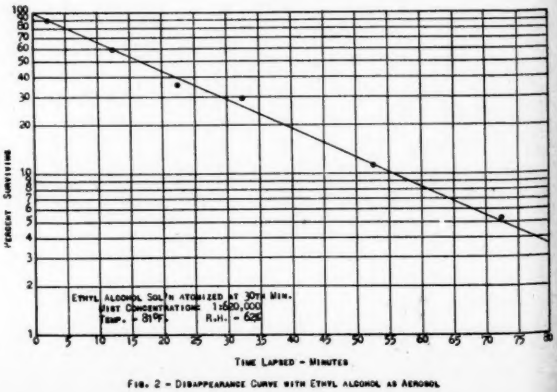
PERCENT SURVIVING
ETHYL ALCOHOL SOLN ATOMIZED AT 30TH MIN.
MIST CONCENTRATION 1:620,000
TEMP. - 81°F. R.H. - 62%
TIME LAPSED - MINUTES

FIG. 2 - DISAPPEARANCE CURVE WITH ETHYL ALCOHOL AS AEROSOL

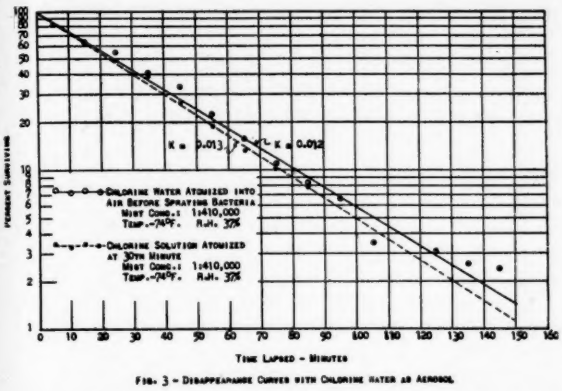

FIG. 3 - DISAPPEARANCE CURVES WITH CHLORINE WATER AS AEROSOL

ance rate should have been greater after atomizing than before. This confirms the findings of Pulvertaft and associates,[4] who indicate that alcohol is not very effective as a bactericidal aerosol. It is possible that alcohol because of its high vapor pressure evaporated very rapidly and did not provide a bactericidal mist.

Figs. 3, 4, and 5 show results of typical experiments using water solutions of chlorine and "Sterichlor" and sodium hypochlorite as aerosols.

The full line-open dot observations in Fig. 3 represent the results obtained with a solution of chlorine gas in water atomized into the air just before the bacteria was sprayed. Sampling for bacteria was started two minutes after their spraying was completed. The disappearance rate, K, for this curve, compared with the natural disappearance rates at about the same temperature and humidity, show that the chlorine had no appreciable effect on the disappearance of the bacteria. The dash line-solid dot observations represent the results when the solution of chlorine gas in water was atomized into the air 30 minutes after starting bacterial sampling. This also shows no appreciable effect on the disappearance of the bacteria.

Since "Sterichlor" is essentially a mixture of chloramine-T and sodium bicarbonate which upon being dissolved in water releases chloramines[19] and since the large quantities of salts in it are slightly hydroscopic, it was thought that the chlorine in the mist as well as the mist itself might be more persistent and thus more effective than a solution of chlorine gas in water. The results in Fig. 4 as well as other results when smaller volumes of the solution were atomized into the air indicate that "Sterichlor" is not effective.

In Fig. 5 are results of experiments in which a sodium hypochlorite solution was atomized into the air 30 minutes after the bacterial sampling was started. The full line-open dot observations show increased disappearance of the bacteria after atomizing the

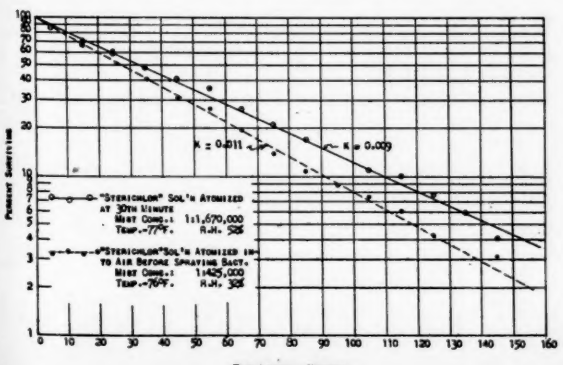

FIG. 4 - DISAPPEARANCE CURVES WITH "STERICHLOR" SOLUTION AS AEROSOL

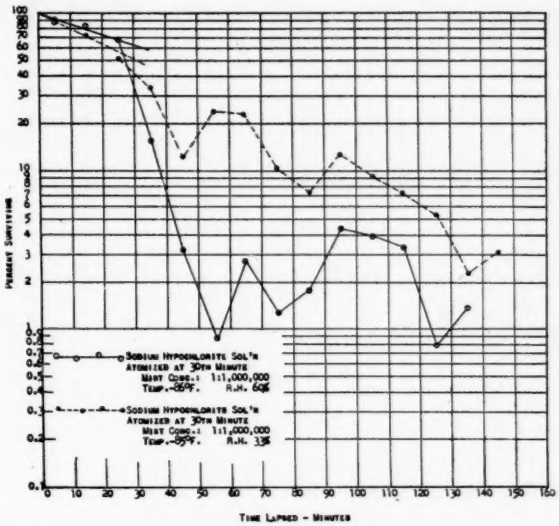
PERCENT SURVIVING
SODIUM HYPOCHLORITE SOL'N ATOMIZED AT 30TH MINUTE
MIST CONC.: 1:1,000,000
TEMP.-68°F. R.H. 60%
SODIUM HYPOCHLORITE SOL'N ATOMIZED AT 30TH MINUTE
MIST CONC.: 1:1,000,000
TEMP.-67°F. R.H. 33%
TIME LAPSED - MINUTES

FIG 5 - DISAPPEARANCE CURVES WITH SODIUM HYPOCHLORITE SOLUTION AS AEROSOL

aerosol while the dash line-closed dot observations show only a slight effect of the aerosol on the disappearance. The conditions of these two experiments were practically the same except for the relative humidity.

Other experiments with sodium hypochlorite showed variations in its effectiveness, however, sufficient results are not available to show conclusively that the variation in results was due to the relative humidity. No doubt the relative humidity influences the effectiveness of a water solution aerosol since the rate of evaporation of the small particles of the mist is lessened with an increase in the relative humidity. Droplets of the aerosol which contain salts do not evaporate to complete dryness, particularly if the salts are hydroscopic, but reach a condition of equilibrium with the moisture in the air. This condition at equilibrium depends upon the relative humidity.

At present one can only speculate as to the reason why the chlorine furnished by sodium hypochlorite was more effective than the chlorine from "Sterichlor" or from the gas dissolved in water. It was observed that the chlorine water solution and the "Sterichlor" solutions released much more chlorine gas into the air than did the sodium hypochlorite solution. When the sodium hypochlorite solution was atomized into the air a slight odor was detectable but when the chlorine water and "Sterichlor" solutions were atomized in small concentrations the odor of chlorine was very strong, and when the larger concentrations were used it was necessary to wear a gas mask. These observations indicate that possibly the HOCl and chlorine gas is not being liberated as rapidly from the sodium hypochlorite aerosol as from the chlorine water or "Sterichlor" solutions. This would indicate that the HOCl and nascent chlorine as gases are not effective air bactericides.

There is considerable disagreement between Twort and associates[20] and Masterman[7, 21] on this point. Masterman states that it is the HOCl gas which is the effective air bactericide, and Twort and associates state that the major part of the bactericidal action is due to the material in the droplet. Time does not permit a review or discussion of their work.

Hill, Smith and Douglas[22] concluded from experiments that sodium hypochlorite exerted a bactericidal effect on *Escherichia coli* suspended in air. However, their report does not show that natural disappearance of the bacteria from the air was considered. Master-

man[22] states that mist concentrations in the range of 1:40,000,000 to 1:50,000,000 are effective. He does not show that natural disappearance was considered. Twort and associates[21] conclude that to be effective the mist concentration of a 1% sodium hypochlorite aerosol should be about 1:1,000,000 by volume. They considered natural disappearance by using separate control experiments. The results in Fig. 5 tend to confirm this value. Greater effectiveness might have been obtained in the experiments presented here by the use of an atomizer in which the size of the droplets could be more accurately controlled.

Figs. 6 and 7 show the results of experiments in which a solution of resorcinol and glycerine was used as the aerosol. It is seen in Fig. 6 that when the resorcinol-glycerine mist was present in the air in a concentration of 1:50,000,000 parts of air no bacteria survived throughout the remaining 60 minutes of the experiment. All experiments in which larger concentrations were used showed the same results. The mist concentration of 1:109,000,000 and 1:272,000,000 did not remove all the bacteria from the air but were quite effective in increasing the rate of disappearance.

The results shown as open dots in Fig. 7 indicate that a mist concentration of 1:544,000,000 produced so small a change in the rate of disappearance that it was not significant since it could have been due to sampling error. Furthermore, if it were not for the 5- or 15-minute observation one line would have fit all the observations almost as well as each of the two lines fit the respective groups of observations. The results using a mist concentration of 1:5,440,000,000 show that it had no effect on the disappearance rate of the bacteria. Experiments in which only a glycerine solution was atomized into the air showed that glycerine was not an effective aerosol. Resorcinol in water was found to be very effective but did not appear to be as persistent as the glycerine solution. These results indicate that the minimal effective mist concentration of the resorcinol-glycerine germicidal aerosol is between 1:272,000,000 and 1:544,000,000 by volume.

These results confirm the experience of Twort and associates[6] who place the minimal effective mist concentration of resorcinol-glycerine aerosols at approximately 1:400,000,000 by volume. They found that hexyl-resorcinol in propylene glycol was considerably more effective than resorcinol and glycerine. Pulvertaft and associates[4] found resorcinol-glycerine solutions to be highly effective as bacterial aerosols but do not give the required concentrations.

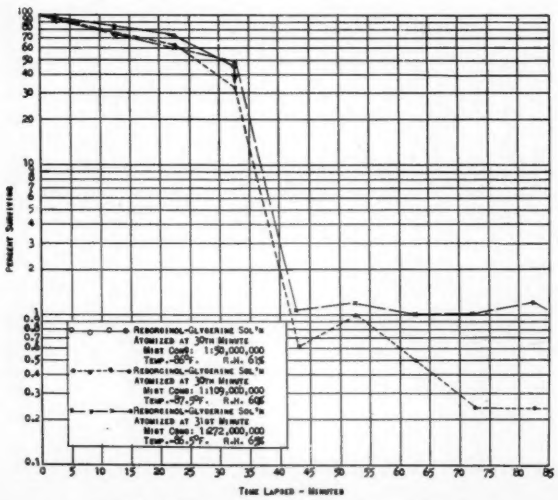

Fig. 6 - Disappearance Curves with Resorcinol and Glycerine as Aerosols

What finally happens to the material in the mist particles that does not evaporate is of importance. In a room where the air is changed several times per hour, it is possible that most of the small droplets would be ventilated out of the room. However, when a droplet strikes a surface it will probably adhere to it. The number of mist droplets which strike surfaces and adhere to them will vary with the air movement and will be greater when the air is being agitated than when there is less movement. It was observed that a film of glycerine formed on the fans after the larger concentrations of resorcinol-glycerine solutions had been atomized into the air. Fine crystals of salt were noticeable on surfaces after "Sterichlor" solutions had been atomized.

The results of this investigation show that:

1. The disappearance of bacteria from air approximately follows a logarithmic relationship with respect to time.

2. The rate of natural disappearance of bacteria from air is relatively high; that is, bacteria introduced into the air do not remain there long even when the air is being circulated.

3. The rate of natural disappearance varies greatly for different bacteria.

4. As suggested by Wells,[16] the disappearance rate appears to vary with the relative humidity, increasing as the relative humidity increases.

5. In the range of temperatures of these experiments, the temperature did not greatly affect the rate of disappearance.

6. Bacteria showing a small natural disappearance rate are more satisfactory as index organisms for air sterilization studies.

7. Natural disappearance rates should be considered in determining the effectiveness of a germicidal aerosol.

8. The method of change in disappearance rate from the natural disappearance rate used herein is an efficient method for studying the effectiveness of bactericidal aerosols.

9. Chlorine water, "Sterichlor," glycerine, and alcohol solutions, did not influence the disappearance of *Staphylococcus aureus* under the conditions of this investigation.

10. Sodium hypochlorite aerosols can effect a reduction in the bacteria in air but require a rather high mist concentration and their efficacy is affected by other conditions.

11. The relative humidity of the air may influence the effectiveness of aerial bactericides.

12. A small mist concentration of a resorcinol-glycerine solution is an effective aerial bactericide.

13. The vapor pressure of the bactericide influences its use and effectiveness as an aerosol.

An aerosol for air disinfection to be of practical

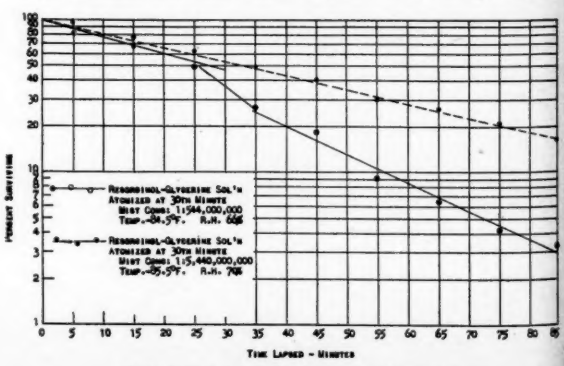

Fig. 7 - Disappearance Curves Using Resorcinol and Glycerine as Aerosols

use in places occupied by people must conform to the following requirements: (1) Non-toxic to man; (2) non-irritant to the eyes and lungs; (3) rapidly lethal to the bacteria when present in small concentrations; (4) inodorous; (5) invisible; (6) non-inflammable; (7) non-corrosive; (8) persistent; and (9) should not leave films and coatings on walls and furniture.

Considerable investigation into the toxicity and other characteristics of aerosol disinfectants is necessary before they can be considered desirable for use in rooms occupied by people. However, they may have a definite use in fields such as air fumigation. The sterilization of air in laboratories, media rooms, storage rooms, etc., can be effected by atomizing a bactericidal aerosol into the room and allowing it to be dissipated before the room is used by people. The sterilization of surfaces offers another use for aerosols.

For the germicidal aerosol to become of wide practical use, it will have to be as satisfactory and efficient as ultra-violet radiation.

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American Industrial Hygiene Association
News of Local Sections

THE New England Section held an Industrial Hygiene Seminar at the Harvard School of Public Health, Boston, Massachusetts, November 28, 1941. The following program was presented:

Metabolism of Carbon Disulfide, by R. W. MCKEE (Harvard School of Public Health).

Air Pollution from a Metallurgical Plant, by W. M. PIERCE (Employers Liability Assurance Corporation, Boston).

Practical Value of Hg Determination in Urine, by H. B. ELKINS (Mass. Division of Occupational Hygiene, Boston).

The Control of Dermatitis in Handling Explosives, by J. B. BUTLER (Lt.-MC-USN, Newport Torpedo Station).

Chloracne from Halowax-Treated Wire, by B. D. TEBBENS (General Electric Company, Schenectady).

Dust-Explosion Apparatus. Demonstration by L. SILVERMAN (Harvard School of Public Health).

Ventilation Engineering in the Control of Industrial Health Hazards, by B. F. POSTMAN (State Department of Health, Hartford, Connecticut).

Safety Shoes in Ship Construction, by H. LIEBER (Lt.-MC-V(S)-USNR, U.S. Navy Yard, Brooklyn, N. Y.).

The Health of Welders, by M. M. GOULD (Lt. Comdr., MC-USN (Ret), Boston Navy Yard).

Studies in Particle-Size Distribution, by W. FRANKLIN (Junior Public Health Engineer, assigned to Massachusetts) and L. SILVERMAN (Harvard School of Public Health).

Magnesium and its Alloys, by C. R. WILLIAMS (Liberty Mutual Insurance Company and Harvard School of Public Health).

THE Metropolitan New York Section was addressed on October 8, 1941, by DR. L. F. CURTISS, Physicist of the National Bureau of Standards, on the subject, "Radium Hazards in Dial Painting." DR. CURTISS described some of the outstanding causes of radium poisoning in dial painting operation as well as some of the effective means for protection of workers from this hazard. In connection with the control of the hazards, he demonstrated the use of the Geiger-Muller counter for determining the concentration of gamma rays in the workroom atmosphere. He also illustrated and described the ionization chamber and the various means used for the evaluation of radon concentration in the atmosphere and in a person's breath. Following his presentation, the speaker answered numerous questions raised by the audience.

The meeting held November 19, 1941, was addressed by MR. R. G. DEWDNEY, Senior Naval Architect attached to the U. S. Navy Yard at Brooklyn. His talk on "Ventilation of a Modern Battleship" was given at the Officers' Club, United States Navy Yard at Brooklyn.

THE Pittsburgh Section held its first fall meeting on November 13, 1941, at 8:00 P.M. at the U. S. Bureau of Mines, Pittsburgh. This meeting was held on the evening following the annual meeting of the Industrial Hygiene Foundation, and it afforded an opportunity for members of the various sections to visit the Pittsburgh Section. About 40 members and guests were present at this meeting, which was addressed by MR. THEODORE F. HATCH, Associate Professor, Depart-

ment of Public Health, University of Pennsylvania, Philadelphia, on "The Design of Modern Industrial Ventilating Systems." A valuable discussion of practical ventilation problems followed the presentation of the formal paper.

THE Michigan Section heard DR. SCHRENK, Chief Chemist of the Health Division, U. S. Bureau of Mines, discuss "Gas Masks and Respirators on December 3, 1941." DR. SCHRENK, who is in charge of the government's official station for the testing and approval of gas masks and respirators, showed a Kodachrome movie on approved testing methods and discussed types of atmospheric contaminants together with the fundamental principles of respiratory protective devices. His authoritative comment on the use, limitations and applications of the various types of respiratory devices included many suggestions for their intelligent application. Published lists of approved respiratory protective devices were available to those attending the meeting. As given in the October INDUSTRIAL HYGIENE SECTION, the next meeting is to be held in Lansing on January 14, 1942.

THE Chicago Section heard MR. E. C. BARNES, Medical Department, Westinghouse Electric & Manufacturing Company, East Pittsburgh, discuss the methods followed by the Westinghouse in establishing periodic physical examinations, control of hazardous materials in new processes, and specific problems which have arisen within the past few months from the introduction of substitute materials. The audience of 75 members and guests received much practical information applicable to their own organizations from MR. BARNES' presentation.

The next meeting of the section to be held on January 8, 1942 is to be addressed by DR JAMES H. STERNER, Laboratory of Industrial Medicine, Eastman Kodak Company, Rochester, New York, who will discuss "Solvent Vapor Exposure." A paper entitled "Medical and Engineering Study of the Carbon Disulfide and Hydrogen Sulfide Exposures in the Synthetic Meat Casing Industry" is to be presented by DR. MILTON H. KRONENBERG and KENNETH M. MORSE, of the Illinois Department of Public Health, Division of Industrial Hygiene. Opportunity is to be provided for a visit to the headquarters and laboratory of the Division prior to the meeting. The technical staff of the Division is to be available to answer questions and demonstrate equipment and apparatus used for industrial hygiene studies.

The Fifty-Third (1942) Annual Meeting of the American Association of Railway Surgeons will be held at the Palmer House, Chicago, September 10-11-12, 1942.

GENERAL

—Continued from page 17

this is equivalent to 108 weeks of lost time. In other words, the time of two men for a full year has been lost because of eye injuries during 10 months of this year."

Minnesota's Program

THE Division of Industrial Health of Minnesota's State Department of Health announces the following general program:

1. To receive and investigate reports of occupational disease.

2. To promote more adequate medical services within industry; such as the employment of full-time or part-time physicians and nurses, the provision of properly equipped first aid rooms, and the maintenance of sickness records.

3. To encourage the use of ethical pre-employment and periodic physical examinations and, as a part of these examinations, the use of the routine serologic test for syphilis. It is advocated that the positive test for syphilis should not be used as a means of discrimination against an employee providing he secures adequate medical treatment, unless he has syphilis in a communicable stage, or sufficient involvement of the heart or central nervous system to be a hazard to himself or his associates.

4. To confer with industrial physicians in regard to special problems or general industrial health programs. Special urine and blood analyses for evidence of industrial intoxication will be done when warranted. Occasional physical examinations will be made as an aid in evaluating the seriousness of certain industrial exposures.

5. To provide engineering personnel who are specially trained and equipped to make studies of plant environment; such as air analysis for toxic vapors, gases, and dust, in effort to determine whether the working atmosphere is safe or otherwise and to make recommendations for the control of health hazards found. These studies will be made at the request of physicians, plant managements, the State Department of Labor and Industry, and others concerned with the health and welfare of the industrial worker.

6. To promote adult hygiene programs within industrial groups; such as the control of tuberculosis, syphilis, and other communicable or preventable diseases. This requires the coordination of other services and facilities within the Health Department.

7. To prepare and disseminate information on various toxic materials and processes, and methods for their control.—L. W. FOKER, M.D., Director, in *Minnesota Med.*, December, 1941.

Cold Vaccines

DR. G. A. SHARE, of Armour and Company's medical department, says that oral vaccine has been given to employees as a cold preventive during the past five years. Colds have been cut 70 to 80%, and employees are so impressed with the results that a large number now buy the preparation to give to their families. DR. SHARE said: "We feel the results are wonderful. Our people start taking the vaccine right after the middle of September. We give one capsule a day for seven days and then recommend that one be taken twice a week until the first of April, when the cold season is pretty well over."

DR. RICHARD J. BENNETT reports an equally successful use of vaccine among 250 workers of United States Steel last year. He said: "We thought we'd be lucky to get 50-50 results. Our figures show this group of workers had 80% fewer colds than the winter before. This year the company doesn't supply the medicine but the employees found it so helpful that they are buying it themselves." DR. BENNETT doesn't give full credit for the reduction in colds to the vaccine itself. He feels it has a beneficial psychological effect in making people more "cold conscious." "When people will go to the trouble to take a vaccine to prevent colds, they are more on the look-out for the first symptoms, more likely to guard against them by observing hygienic rules." At the mills operated by the United States Steel workers are given ultra-violet light treatments and vitamins to build up their resistance to colds.

Another large Chicago manufacturing plant reports that among a selected group of employees who took cold-preventive capsules last year, 66% reported no colds, 15% mild colds and 19% severe colds. The management finds these results so hopeful that this year the treatment has been extended to all workers who wish to take it.

Most firms making an organized effort to combat the common cold spend from $5,000 to $6,000 a year for medication alone, exclusive of the cost of its administration and the check that must be kept by doctors and nurses. It's well worth the money, because they estimate that they save approximately $26,000 in time that would otherwise be lost through illness.—From an article in the Pictorial Review of *Chicago Herald-American*, December 7, 1941.

The Twenty-Seventh (1942) Annual Meeting of the American Association of Industrial Physicians and Surgeons and the Third (1942) Annual Meeting of the American Industrial Hygiene Association will be held at Cincinnati, Ohio, April 13-17, 1942.